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Coastal City Adaptation Project (CCAP) Agreement No. AID-656-C-14-00001

Water Quality Assurance Plan (WQAP)



November 2015

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ACRONYMS

AOR	Agreement Officer's Representative
CCAP	Coastal City Adaptation Project
COP	Chief of Party
COR	Contracting Officer's Representative
EMMP	Environmental Mitigation and Monitoring Plan
GOM	Government of Mozambique
GUC	grant under contract
IEE	Initial Environmental Examination
IP	Implementing Partner
IR	Intermediate Result
MEO	Mission Environmental Officer
NGO	Non-Governmental Organization
WHO	World Health Organization
WQAP	Water Quality Assurance Plan

Cover Photo: Rainwater catchment system used in Madal, east of Quelimane.

1. Introduction

The purpose of this Water Quality Assurance Plan (WQAP) is to ensure that the sources of drinking water supported by the USAID-funded Coastal City Adaptation Project (CCAP) in Mozambique provide water that is safe for human consumption. It was prepared in conformance with the Initial Environmental Evaluation (IEE) for the CCAP (USAID 2015), which requires that a WQAP be prepared as a condition for the provision of drinking water.

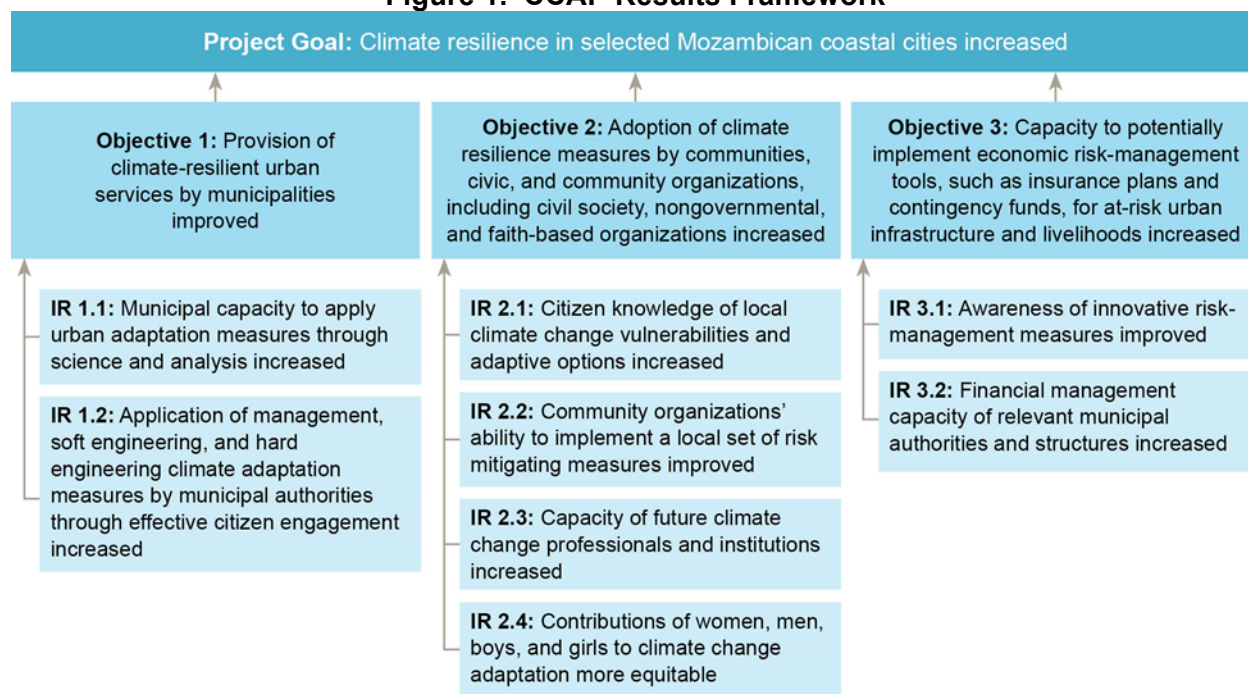
This WQAP has been prepared in consultation with the cognizant COR, Colin Quinn, and the MEO, Eduardo Langa, in USAID/Mozambique. CCAP also consulted with personnel from USAID's Global Health Bureau in Washington, DC concerning applicable sampling methodology.¹

2. Background

Overview of CCAP Mozambique

The CCAP is a 5-year, \$15 million USAID-funded project with the goal to increase climate resilience in selected Mozambican coastal cities by assisting vulnerable coastal cities to incorporate climate change projections into their planning processes and to undertake adaptive measures. CCAP focuses its initial interventions in two municipalities: Pemba and Quelimane. In the future, CCAP may identify a few key, very successful interventions and scale them in additional cities along the Mozambican coast with similar conditions and climate change adaptation needs as those in Pemba and Quelimane.

Figure 1. CCAP Results Framework



¹ Personal communication by Lane Krah, Environmental Impact Assessment Specialist for CCAP, with Rochelle Rainey, Senior Advisor, Environmental Health, USAID Global Health Bureau via e-mails dated October 3 and October 6, 2015.

The CCAP Results Framework is presented in Figure 1. The activities covered by this WQAP fall under Objective 2, IR 2.2, Community organizations' ability to implement a local set of risk mitigating measures improved. The specific activity for which this WQAP has been developed is:

Plan, implement, and manage GUCs, sub-contracts and other funding mechanisms that provide financial, technical and capacity support to local universities, students, and NGOs to support cost-effective potable water solutions, primarily focusing on rainwater harvesting systems.

IEE Determination for Potable Water Activities of CCAP

The IEE gave the potable water activities of CCAP a negative determination subject to the following four conditions (USAID 2015, pp 33-35):

1. The activity shall be designed and implemented using the principles and good construction practices provided in USAID's Sector Environmental Guidelines for Small-Scale Construction (<http://www.usaidgems.org/Sectors/construction.htm>) and using best practices for roof-harvested rainwater, such as:
 - UNEP/OAS. 1998. Rainwater harvesting from rooftop catchments. In: Sourcebook of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean. <http://www.oas.org/dsd/publications/unit/oea59e/ch10.htm>
 - International Relief and Development (IRD). 2013. Roof-Top Rainwater Harvesting Best Practices Guide. USAID-funded. http://www.ird.org/uploads/IRD_RWH_Guide_10June13.pdf
 - These principles must be specified in the EMMP.
2. The implementing partner shall develop and implement a training program for water recipients on the operation and maintenance of roof-harvested rainwater systems, the potential for microbiological contamination, and proper treatment for safe drinking water.
3. The implementing partner shall conduct follow-up inspections to ensure that proper operation and maintenance and treatment of drinking water are being practiced.
4. Prior to drinking water provision, the project will prepare and receive approval for a Water Quality Assurance Plan (WQAP).
 - The WQAP will be prepared in consultation with the cognizant AOR/COR and/or Activity Manager. Its purpose is to ensure that all new and rehabilitated USAID-funded sources of drinking water provide water that is safe for human consumption. The completed WQAP must be approved by: the AOR/COR and/or Activity Manager; the MEO; and the REA.
 - Once approved, the WQAP must be implemented in full, and for the duration of drinking water activities. Implementation must include testing of water prior to making the supply point available to beneficiaries.
 - The WQAP constitutes a key element of the project's EMMP. As with all other elements of the EMMP, project budgets, workplans, and staffing plans must

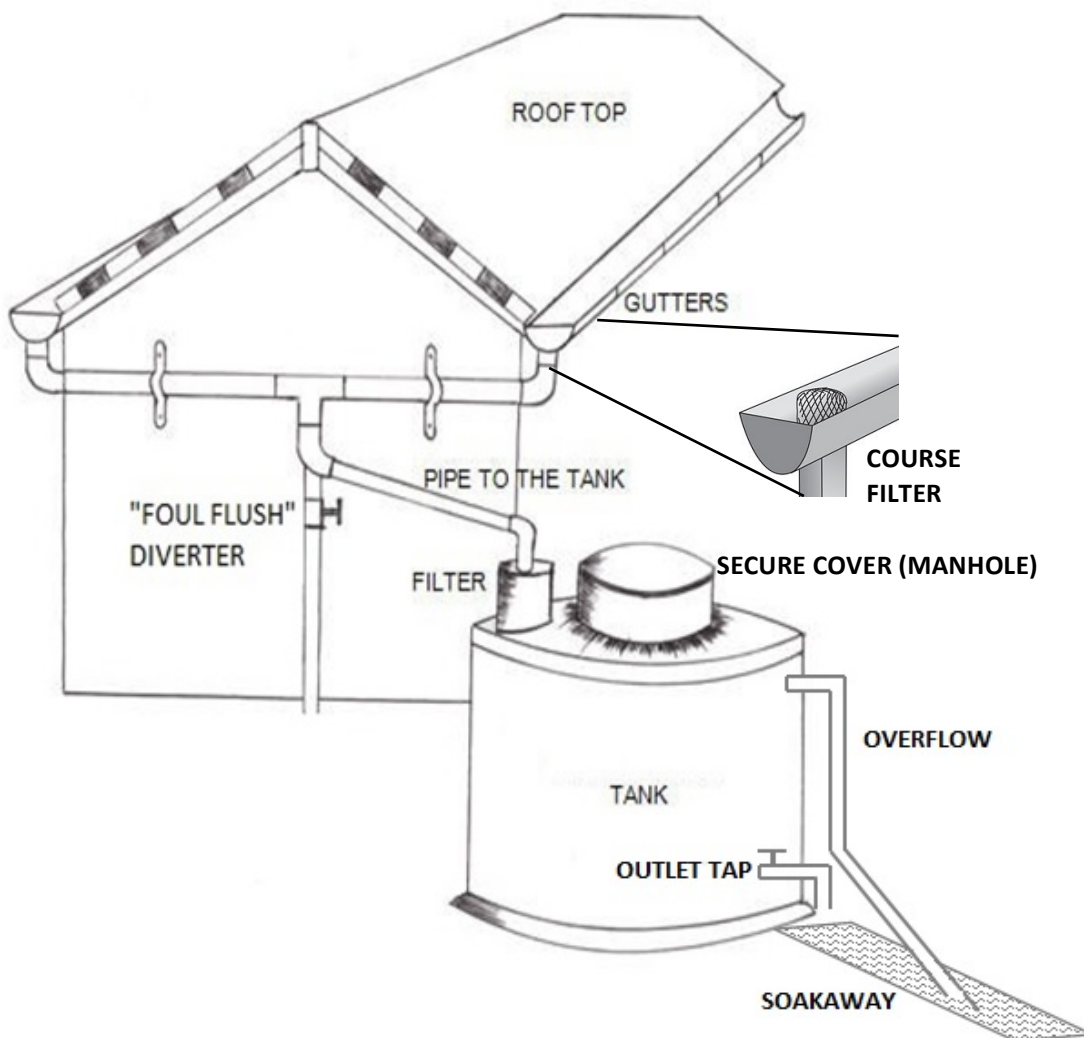
provide for its full implementation. The approved WQAP must include at minimum the following sections:

- Project information (name of project, name of IP, period of performance, contact information, name of COR/AOR)
 - A description of the drinking water points to be subject to the WQAP (approximate numbers, water source(s), technology(ies), general geographic area and installation context).
 - An inventory of applicable water quality standards, including those promulgated by USAID, as well as the cognizant host-country regulatory entity/entities. (The World Health Organization [WHO] Guidelines for Drinking-water Quality may be substituted for host-country standards that are not accessible, unclear or outdated.)
 - The responsible parties/entities/institutions, under host country law or policy, for monitoring and managing water quality of the water points subject to this WQAP. If other than the IP, a summary assessment of their capacity and their involvement.
 - A technical assessment of the equipment, resources and expertise that will be required to monitor and report on compliance with applicable water quality standards. This should include, for example, sampling materials, reagents, transportation, storage, laboratory facilities and capacity, communications, training or certification criteria, etc.
 - Protocol for initial testing and ongoing monitoring of water quality, to include:
 - contaminants for which initial testing and ongoing monitoring will be conducted
 - water quality assessment methods, including test type and frequency
 - data management and reporting; the project must maintain a central registry of monitoring results by water point and date; GPS coordinates for water points are expected
 - designation of 'responsible party' for each aspect of protocol response procedures in the event water does not meet water quality standards
 - Justification for NOT testing to any applicable standard
 - Sustainability strategy to the extent that responsibility for longer-term water quality assurance will transition in part or whole to project partners or beneficiaries. A summary assessment of the capacity of these partners, and any capacity building to be undertaken
- The WQAP should follow any applicable USAID guidance, as well as local laws, regulations and policies.

3. Description of the Drinking Water Points to be Subject to the WQAP

CCAP will promote and support the construction, operation and maintenance of simple, household-level, roof-harvested rainwater systems (Figure 2).

Figure 2. Roof-Harvested Rainwater System Design



As shown in Figure 2, and required by CCAP's Environmental Mitigation and Monitoring Plan (EMMP) (Chemonics 2015), the systems will have several design and management features to improve the quality of collected water, including:

- The use of inert, nontoxic material for the roof and the collection and storage structures;
- Avoidance or removal of overhanging vegetation;
- A "foul flush" diverter, to divert the first flow off of the roof away from the tank;
- A coarse gutter filter and a finer tank inlet filter;
- A solid secure tank cover;
- An overflow pipe;
- A manhole, sump, and drain to facilitate cleaning;
- An extraction system that does not contaminate the water; e.g., a tap or pump; and
- A soakaway to prevent spilled water from forming puddles near the tank.

Also, in accordance with the EMMP, the system owners will be informed of the potential for microbiological contamination and trained in proper treatment for safe drinking water. Untreated

roof-harvested rainwater is not potable, as it can become contaminated while falling through the atmosphere, from contaminants on the roof and in the gutters, and from contaminants that may enter the storage tank. Therefore, the treatment of water after removal from the storage tank and before potable use will be integral to the CCAP roof-harvested rainwater program, and the drinking water points to be subject to this WQAP is the water in the containers in which water will be stored after treatment.

CCAP will be directly involved in the installation of at least 24 roof-harvested rainwater systems, with the aim of stimulating replication to many more potential beneficiaries in the two target areas. The systems will be managed by the owner of the roof from which the water is collected.

The rainy season in Mozambique usually extends from November through April, so this will be the time of the year when the systems will be collecting water. Users of the water may have access through June or July, depending upon the tank size and individual water use characteristics. So the water from these systems will be in use for seven to nine months. During other periods, individuals will haul water from other sources (primarily local wells, but also some public water system community taps), as they do now.

4. Regulatory Framework for Drinking Water Quality

Water Quality Standards

The Water Law (No. 16 of 1991) authorizes the Ministry of Health to establish drinking water quality standards. The Ministry of Health promulgated regulations for drinking water quality with Ministerial Order No. 180 of 2004 (GOM 2004). The standards are presented in Annex A of this WQAP. All of the standards are equal to or more stringent than the WHO recommended standards (WHO 2011). The Ministerial Order also prescribes the analytical laboratory methods that must be used to analyze drinking water quality samples (GOM 2004, Annex III).

Regulatory Responsibilities

The Ministry of Health is the competent authority for the regulation of drinking water quality. Under Ministerial Order No. 180 of 2004 (GOM 2004), the National Directorate of Health (Direcção Nacional de Saúde, DNS) is designated as the regulatory authority at the national level. The DNS carries out these responsibilities at the central government level through its Department of Environmental Health (Departamento de Saúde Ambiental) and the National Laboratory for Food and Water Hygiene (Laboratório Nacional de Higiene de Águas e Alimentos). Provincial and local governmental entities involved in the regulation of drinking water quality are the provincial Centers for Environmental Health and Medical Examinations (Centros de Higiene Ambiental e Exames Médicos) and the provincial Water Laboratories (Laboratórios Provinciais de Água) and at the local level by the Health Centers (Centros de Saúde). The operator of the system has the responsibility to take actions to control drinking water quality, including taking and analyzing water quality samples. Table 1 shows the responsibilities given to each of these entities by the Ministerial Order No. 180 of 2004.

Table 1. Regulatory Responsibilities for Drinking Water Quality

Entity	Regulatory Responsibility
Department of Environmental Health	<ul style="list-style-type: none"> • Provide oversight, planning and evaluation of the implementation of Ministerial Order No. 180 of 2004 • Promote, provide and participate in training at the national and international level • Advocate for the provision of clean drinking water
National Laboratory for Food and Water Hygiene	<ul style="list-style-type: none"> • Provide technical support to the Department of Environmental Health in the implementation of Ministerial Order No. 180 of 2004 • Serve as a reference laboratory to ensure quality control for the national network of laboratories doing analysis of drinking water quality • Serve as the laboratory for the city and province of Maputo
Provincial Centers for Environmental Health and Medical Examinations	<ul style="list-style-type: none"> • Ensure that inspections of drinking water sources are conducted and that drinking water quality samples are collected • Ensure that appropriate practices are adopted at sources of drinking water to protect the health of the consumer
Provincial Water Laboratories	<ul style="list-style-type: none"> • Ensure that inspections, collections of samples of drinking water and analysis of those samples are properly conducted
Local Health Centers	<ul style="list-style-type: none"> • Designate a Water Inspector with the responsibility to inspect source of drinking water • The Water Inspector may or may not be equipped with a field kit for testing water quality
Water System Operator	<ul style="list-style-type: none"> • Develop and implement a drinking water quality program including a water quality sampling program complying with the requirements of Ministerial Order No. 180 of 2004 • Maintain records of water quality • Regularly report to the competent authorities and the public on the quality of water supplied • Report immediately to the competent authorities if a drinking water quality sample is violated and communicate such reports to the public, as directed by the authorities
Source: Ministerial Order No. 180 of 2004, Articles 6 and (GOM 2004)	

Applicability to CCAP Activities

Ministerial Order No. 180 of 2004 is quite comprehensive in regards to assuring the quality of drinking water provided by water system operators; however, it is not applicable to the water that will be provided by CCAP through its promotion of roof-harvested rainwater systems. Article 9 of the Ministerial Order allows exemption from its requirements for water systems that provide less than 10 m³/day of water for consumption. Article 20 specifically exempts water sources for individual use from the regulation. The roof-harvested rainwater systems promoted by CCAP will provide well under 10 m³/day of water for consumption² and will, with rare exception, be for individual use³.

² Most African countries have adopted 20-35 liters/person/day as basic water requirement to meet consumption and cleaning needs (AfDB 2008, pg 13). Using the upper limit of this value, 10 m³/day would serve 285 individuals, a capacity far exceeding any system being considered for support by CCAP.

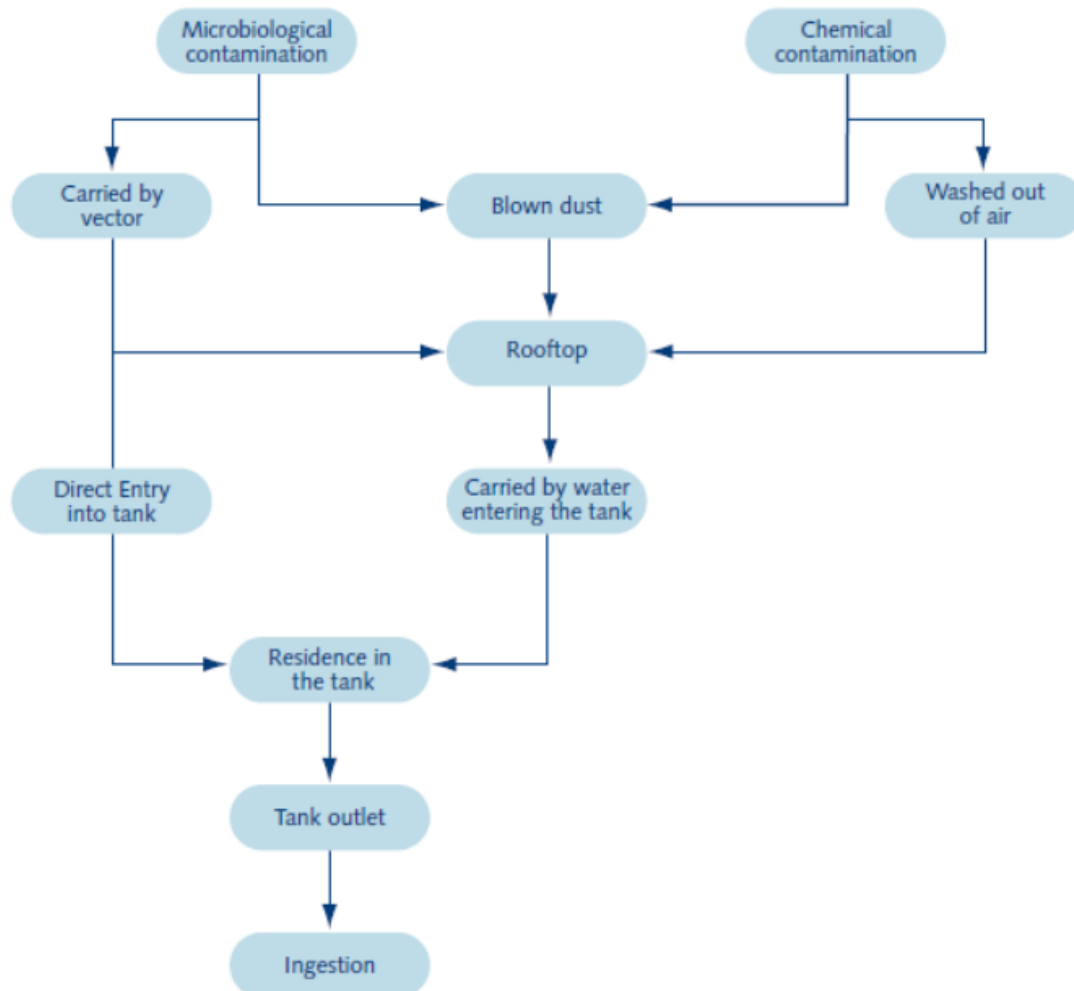
³ CCAP may support construction of a system at a school for use in hand washing and drinking (after treatment). Such a system would have a per capita daily use of 5-10 liters per day.

5. Contaminants of Concern

The primary contaminant of concern is fecal coliform, associated with microbiological contamination. To a much lesser extent, nitrate is of potential concern.

Rainwater begins as distilled water. It can become polluted by passing through contaminants during its fall to the earth and from picking up contaminants from the roof and the collection and storage structures. The primary pathways of contamination for roof-harvested rainwater systems are shown in Figure 3.

Figure 3. Contamination Pathways for Roof-Harvested Rainwater Systems



Source: Thomas and Martinson 2007, Figure 3.1, pg. 38

Chemical contamination is generally only an issue where roof-harvested rainwater systems are located near to heavy chemical/industrial operations, high density urban areas with air pollution problems, or large agricultural areas with extensive pesticide applications. These situations do not exist in the areas where CCAP will be active.

Although the rooftop environment is not conducive to survival of microbiological contaminants, they can find their way into storage tanks, and have repeatedly been identified as the major

contaminant of concern for roof-harvested rainwater systems (Owusu-Boateng 2015, Achadu et al. 2013, Ahmed et al. 2011, Mendez et al. 2010, and Heijnen et al. 2007). The principal sources of microbiological contamination in roof-harvested rainwater systems are feces from and corpses of birds, reptiles and small mammals and organic debris (e.g., leaves and twigs) collected on roofs. Foul flush designs and the use of screens and secure covers on storage tanks (which will be promoted by CCAP) can greatly reduce these contaminants, but studies that sampled water after the use of foul flush and in the storage tanks have consistently identified microbiological contaminants as still being present in the water. Therefore untreated roof-harvested rainwater can be expected to contain microbiological contaminants, including fecal coliform, which can cause gastro-intestinal disease.

Literature review indicates that nitrate contamination is not generally a problem with roof-harvested rainwater. Where it has been monitored, it has been found at levels well below Mozambique's and WHO's drinking water standard of 50 mg/l (Owusu-Boateng 2015, Achadu et al. 2013, Mendez et al. 2010, and Nicholson et al. 2005). During consultation with USAID/Mozambique, however, concern for potential nitrate contamination was cited as a concern due to the use of some roofs as areas where birds roost or otherwise congregate.

USAID requirements for testing drinking water for arsenic applies only to drinking water provided from well water⁴. Only one study was identified that sampled for arsenic in roof-harvested rainwater (Mendez et al. 2010). This study was conducted in Texas, USA. It found that levels of arsenic in roof-harvested rainwater ranged from 0.00058 to 0.00097 mg/l with an mean value of 0.00091 mg/l, which is less than 1/10th of Mozambique's and WHO's drinking water standard of 0.01 mg/l for arsenic.

6. Water Quality Sampling Program

The water quality sampling program presented in this section was developed using the following criteria:

- Sample and test for the Contaminants of Concern.
- Use methodologies appropriate for areas with limited infrastructure and financial resources.
- Use methodologies that are sustainable – that the Implementing Partners (IPs) will be capable of using after CCAP concludes.

Initial Water Quality Testing

At the beginning of the first rainy season after the installation of each roof-harvested rainwater system, CCAP or its IPs will complete the following water quality tests for treated water (from the container in which treated water is stored):

1. ***Escherichia coli (E. coli)***.⁵ Test treated drinking water at each household where a new system has been installed for no detectable *E. coli* in any 100 ml sample⁶. Initial *E. coli* testing will be conducted using low-cost field test kits, which CCAP will obtain from an overseas vendor. Collection and testing protocols for *E. coli* are presented in Annex B.

⁴ Guidance Cable State 98 108651, June 16, 1998 and subsequent USAID guidance (USAID 2003).

⁵ WHO recommends monitoring *E. coli* in community-managed and household water systems, as a readily measureable indicator organism for fecal contamination (WHO 2011, pg 75).

⁶ *E. coli* drinking water standard for Mozambique (GOM 2004) and recommended by WHO (WHO 2011) for treated drinking water.

2. **Nitrate.** Visually inspect the roof and gutters to determine if there is evidence of concentrated bird droppings due to the use of the structure for roosting or other congregations of birds. If such evidence is present, test treated drinking water for nitrate concentrations at a level not to exceed 50 mg/l⁷. Initial nitrate testing (if necessary) will be conducted using low-cost field test kits, which CCAP will obtain from an overseas vendor. Sample collection and reporting will be the same as that for *E. coli*, as presented in Annex B. Sample analysis will be done in accordance with the field kit manufacturer's directions.

Water Quality Monitoring

CCAP or its IPs will monitor water quality of treated water (from the container in which treated water is stored) at each roof-harvested rainwater system supported by CCAP, testing for the following contaminants twice per year, once at the beginning of the rainy season and once near the end of the rainy season:

1. ***E. coli.*** CCAP will test drinking water at each household where a system supported by CCAP has been installed for no detectable *E. coli* in any 100 ml sample. *E. coli* testing will be conducted using the same technology and sampling method as the initial *E. coli* water quality test.
2. **Nitrate.** Visually inspect the roof and gutters to determine if there is evidence of concentrated bird droppings due to the use of the structure for roosting or other congregations of birds. If such evidence is present, test treated drinking water for nitrate concentrations at a level not to exceed 50 mg/l. Nitrate testing (if necessary) will be conducted using the same technology and sampling method as the initial nitrate water quality test.

Response Protocol

If the initial water quality testing or the water quality monitoring, indicate that the contaminant level does not exceed the thresholds established in this WQAP, CCAP or its IPs will inform the system owner of the results.

If the initial water quality testing or the water quality monitoring indicates that contaminant levels exceed the thresholds established in this WQAP, CCAP or its IPs will take the following actions:

1. Inform the system owner of the test results, and review with the system owner the threat to health associated with drinking contaminated water.
2. Review with the system owner the necessary water treatment procedures, and ensure that the owner and others responsible for treating drinking water are knowledgeable and capable of correctly treating the water collected by the roof-harvested rainwater system.
3. Conduct a thorough review of the system condition and maintenance practices and secure a commitment from the system owner to correct any deficiencies.

⁷ Nitrate drinking water standard for Mozambique (GOM 2004) and recommended by WHO (WHO 2011).

4. Return to the system in one week to ensure that deficiencies have been corrected and to retest the drinking water.
5. If the water continues to be tested as being contaminated, CCAP or its IPs will ensure that the sampled water access point is restricted to non-potable uses only.

7. Other Program Components to Ensure Safe Drinking Water

Water quality testing is only one component of water quality assurance. Proper system design, construction, operation and maintenance is critical for assuring that drinking water quality standards are met. Acknowledging this need, CCAP's EMMP included specific mitigation measures and monitoring requirements for its roof-harvested rainwater system activities. Their implementation is critical for assuring safe drinking water, and as such they have been included in this WQAP. The EMMP requirements for roof-harvested rainwater systems are presented in Annex C. The monitoring log for inspecting CCAP-supported roof-harvested rainwater systems is presented in Annex D.

8. Reporting and Recordkeeping

Reporting on implementation of the WQAP will be completed as part of overall CCAP environmental compliance reporting to USAID, as specified in the CCAP EMMP (Chemonics 2015). All documentation generated in support of this WQAP will be retained as part of the project record, and provided to USAID at its request. This includes technical specifications for the establishment, installation or rehabilitation of water access points, as well as monitoring logs and similar compliance records.

9. Project Responsible Parties

The following named positions are responsible for overseeing implementation of the CCAP WQAP.

- a. The CCAP Deputy Chief of Party for Programs has overall responsibility for ensuring that CCAP implements the WQAP and that CCAP complies with all IEE conditions and environmental mitigation and monitoring requirements. This includes ensuring that WQAP implementation is included in work plans and budgets.
- b. The CCAP Municipal Advisor in the municipality where an activity is undertaken has initial responsibility for:
 - Inspecting roof-harvested rainwater systems;
 - Collecting, analyzing, and reporting on water quality sampling; and
 - Implementing response procedures.
- c. The CCAP Municipal Advisor, in consultation with the CCAP Deputy Chief of Party for Programs, has responsibility for determining when it is appropriate to turn inspecting and water quality monitoring and reporting responsibilities over to the relevant IP. This determination will be based on the technical capacity of the IP technical staff to implement the CCAP EMMP and WQAP for its roof-harvested rainwater system activities.
- d. After the CCAP Municipal Advisor has determined that an IP is capable of implementing the WQAP, the technical staff of the IP will have responsibility for:

- Inspecting roof-harvested rainwater systems;
 - Collecting and analyzing water quality samples;
 - Reporting to the relevant CCAP Municipal Advisor on:
 - Roof-harvested rainwater system inspections;
 - Water quality sampling activities and results; and
 - Implementing response procedures.
- e. The CCAP Municipal Advisor in the municipality where an activity is undertaken has responsibility for providing inspection and monitoring results to the CCAP Deputy Chief of Party for Programs and the CCAP Monitoring and Evaluation Specialist.

10. References

- Achadu, O.J, F.E. Ako, and C.L. Dalla. 2013. Quality Assessment of Stored Harvested Rainwater in Wukari, North-Eastern Nigeria: Impact of Storage Media. IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT), Volume 7, Issue 5 (Nov. - Dec. 2013), pp 25-32. <http://www.iosrjournals.org/iosr-jestft/papers/vol7-issue5/D0752532.pdf>
- African Development Bank (AfDB). 2008. Rainwater Harvesting Handbook: Assessment of Best Practises and Experience in Water Harvesting. AfDB Group, Tunis-Belvédère, Tunisia. 72pp. <http://www.rural-water-supply.net/en/resources/details/268>
- Ahmed, W., T. Gardner, and S. Toze. 2011. Microbiological Quality of Roof-Harvested Rainwater and Health Risks: A Review. J. Environ. Qual. 40:1–9. http://www.researchgate.net/publication/215503892_Microbiological_Quality_of_Roof-Harvested_Rainwater_and_Health_Risks_A_Review
- Chemonics. 2015. Environmental Mitigation and Management Plan for the Coastal City Adaptation Project. Chemonics for USAID/Mozambique. 70pp.
- Government of Mozambique (GOM). 2004. Regulamento sobre a Qualidade da Agua para O Consumo Humano (Regulation of Water Quality for Human Consumption). Diploma Ministerial n. 180/2004, Boletim da República, I Série -Número 37, September 15, 2004, pp 367-380. <http://faolex.fao.org/docs/pdf/moz65565.pdf>
- Heijnen, Han, Namrata Pathak, and M. Feroze Ahmed. 2007. WHO draft guidelines for use of rainwater for human consumption. In: Rainwater and Urban Design 2007. [Barton, A.C.T.]: Engineers Australia, 2007: [372]-[379]. <http://www.eng.warwick.ac.uk/ircsa/pdf/13th/Heijnen.pdf>
- International Relief and Development (IRD). 2013. Roof-Top Rainwater Harvesting Best Practices Guide. USAID-funded. 22pp. http://www.ird.org/uploads/IRD_RWH_Guide_10June13.pdf
- Mendez, Carolina B., Brigit R. Afshar, Kerry Kinney, Michael E. Barrett, and Mary Jo Kirisits. 2010. Effect of Roof Material on Water Quality for Rainwater Harvesting Systems. January 2010. Texas Water Development Board, Austin, Texas. 55pp. https://www.twdb.texas.gov/innovativewater/rainwater/projects/rainquality/2011_02_rainquality_final_rpt.pdf

- Metcalf, Robert H. and Lars Onsager Stordal. 2010. A Practical Method for Rapid Assessment of the Bacterial Quality of Water: A Field-Based Guide. United Nations Human Settlements Programme (UN-HABITAT), Nairobi, Kenya. 12pp.
<http://mirror.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3056>
- Nicholson, Natasha T., Brett V. Long, and Shirley E. Clark 2005. Rainwater Harvesting for Landscape Irrigation: The Good, the Bad, and the Ugly Side of Roof Runoff. Water Resources Group, Department of Civil and Environmental Engineering, Penn State Harrisburg, Middletown, PA. On HarvestH2o website.
http://www.harvesth2o.com/RWH_good_bad_ugly.shtml
- Owusu-Boateng, G. 2015. Domestic Rainwater Harvesting in a Water-Stressed Community and Variation in Rainwater Quality from Source to Storage. Consilience: The Journal of Sustainable Development, Vol. 14, Iss. 2 (2015), pp. 225–243.
<http://www.consiliencejournal.org/index.php/consilience/article/viewFile/437/247>
- Thomas, T.H. and D.B. Martinson. 2007. Roofwater Harvesting: A Handbook for Practitioners. Delft, The Netherlands, IRC International Water and Sanitation Centre. (Technical Paper Series; no. 49). 160 p.
http://www.samsamwater.com/library/Roofwater_Harvesting_-_a_Handbook_for_Practitioner_-_TH_Thomas_and_DB_Martinson.pdf
- UNEP/OAS. 1998. Rainwater harvesting from rooftop catchments. In: Sourcebook of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean. <http://www.oas.org/dsd/publications/unit/oea59e/ch10.htm>
- USAID. 2015. Initial Environmental Examination and Approval Face Sheet, Coastal City Adaptation Project, Mozambique. Approved by AFR Bureau Environmental Officer on June 22, 2015, Mozambique_CCAP_IEE_062215.doc. 51pp.
<http://gemini.info.usaid.gov/egat/envcomp/repository/pdf/43811.pdf>
- USAID. 2014. Sector Environmental Guidelines: Small-Scale Construction. Prepared by The Cadmus Group, Inc. under USAID's Global Environmental Management Support Program. 39pp. <http://www.usaidgems.org/Sectors/construction.htm>
- USAID. 2003. Guidelines for Determining the Arsenic Content of Ground Water in USAID-Sponsored Well Programs in Sub-Saharan Africa.
- World Health Organization (WHO). 2011. Guidelines for Drinking-Water Quality, 4th ed. Geneva, Switzerland, World Health Organization. 564pp.
http://www.who.int/water_sanitation_health/publications/dwq_guidelines/en/

ANNEX A

MOZAMBIQUE DRINKING WATER QUALITY STANDARDS

From: Diploma Ministerial n. 180/2004 (GOM 2004)

15 DE SETEMBRO DE 2004

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Anexo I

Parâmetros de qualidade de água destinada ao consumo humano e seus riscos para a saúde pública

Parte A – Para a água tratada destinada ao consumo humano fornecida por sistemas de abastecimento público, redes de distribuição, camiões ou navios cisternas, ou utilizada numa empresa da indústria alimentar.

1- Parâmetros microbiológicos

Parâmetro	Limite máximo admissível	Unidades	Riscos para a Saúde Pública
Coliformes totais	Ausente	NMP*/ 100 ml N.º de colónias/ 100 ml	Doenças gastrointestinais
Coliformes fecais	Ausente	NMP*/ 100 ml N.º de colónias/ 100 ml	Doenças gastrointestinais
Vibrio cholerae	Ausente	1000 ml	Doenças gastrointestinais

(NMP): Número Mais Provável

2- Parâmetros físicos e organolépticos

Parâmetro	Limite máximo admissível	Unidades	Riscos para a Saúde Pública
Cor	15	TCU	Aparência
Cheiro	Inodoro		Sabor
Condutividade	50-2000	µhmo/cm	
pH	6,5-8,5		Sabor, corrosão, irritação da pele
Sabor	Insípido		
Sólidos totais	1000	mg/l	Sabor, corrosão
Turvação	5	NTU	Aparência, dificulta a desinfecção

3- Parâmetros químicos

Parâmetro	Limite máximo admissível	Unidades	Riscos para a Saúde Pública
Amoníaco	1,5	mg/l	Sabor e cheiro desagradável
Alumínio	0,2	mg/l	Afecta o sistema locomotor e causa anemia
Arsénico	0,01	mg/l	Cancro da pele
Antimónio	0,005	mg/l	Cancro no sangue
Bário	0,7	mg/l	Vasoconstrição e doenças cardiovasculares
Boro	0,3	mg/l	Gastroenterites e eritemas
Cádmio	0,003	mg/l	Vasoconstrição urinária
Cálcio	50	mg/l	Aumenta a dureza da água
Chumbo	0,01	mg/l	Intoxicação aguda
Cianeto	0,07	mg/l	Bócio e paralisia
Cloretos	250	mg/l	Sabor desagradável e corrosão
Cloro residual total	0,2-0,5	mg/l	Sabor e cheiro desagradável
Cobre	1,0	mg/l	Irritação intestinal
Crómio	0,05	mg/l	Gastroenterites, hemorragias e convulsões
Dureza total	500	mg/l	Depósitos, corrosão e espumas
Fósforo	0,1	mg/l	Aumenta a proliferação dos microorganismos
Ferro total	0,3	mg/l	Necrose hemorrágica
Fluoreto	1,5	mg/l	Afecta o tecido esquelético
Matéria orgânica	2,5	mg/l	Aumenta a proliferação dos micro-organismos
Magnésio	50	mg/l	Sabor desagradável
Manganês	0,1	mg/l	Anemia, afecta o sistema nervoso
Mercúrio	0,001	mg/l	Distúrbios renais e neurológicos
Molibdénio	0,07	mg/l	Distúrbios urinários
Nitrito	3,0	mg/l	Reduz o O ₂ no sangue
Nitrato	50	mg/l	Reduz o O ₂ no sangue
Níquel	0,02	mg/l	Eczemas e Intoxicações
Sódio	200	mg/l	Sabor desagradável
Sulfato	250	mg/l	Sabor e corrosão
Selénio	0,01	mg/l	Doenças cardiovasculares
Sólidos totais dissolvidos	1000	mg/l	Sabor desagradável
Zinco	3,0	mg/l	Aparência e sabor desagradáveis
Pesticidas totais	0,0005	mg/l	Intoxicações e distúrbios de várias ordens
Hidrocarbonetos aromáticos policíclicos	0,0001	mg/l	Sabor desagradável, intoxicações e distúrbios de várias ordens

ANNEX B

SAMPLING AND TESTING PROTOCOL FOR *E. COLI*⁸

Materials (Figure B-1)

- Colilert Predisposed MPN tubes (IDEXX, Westbrook, Maine)
- 4 oz (100ml) Standup Whirl-Paks (Nasco, Modesto, CA)
- Sterile plastic pipettes, graduated, individually wrapped
- Battery-operated, long-wave (365-nm) UV lamp

Sample Collection

1. Label the Whirl-Pak bag with sample information, such as location and date/time.
2. Carefully tear off the top plastic section along the perforation. The inside of the Whirl-Pak is sterile, and you should be careful not to contaminate it with your fingers.
3. Open the Whirl-Pak by pulling away on the two white tabs in the top center of the bag.
4. Collect a water sample by running or pouring water into the Whirl-Pak, or by dipping the Whirl-Pak into a water source (and not your hands with it!). Fill the Whirl-Pak to a little above the 100 ml level.
5. Once the sample has been collected, pull the ends of the wires together to close the Whirl-Pak. Then whirl it three complete revolutions to seal it.

Testing Procedure

These procedures should be conducted within 6 hours from collecting the water sample.

1. Carefully remove a sterile pipette from its package, taking care not to touch the end of the pipette that will be inserted into the water sample.
2. Carefully remove the cap of the Colilert tube so as not to contaminate the cap or the tube nor spill any reagent from the tube.
3. Using the pipette, add 10 ml of the water sample to the tube – to the mark on the tube (Figure B-2).
4. Replace the cap. Mix the water with the reagent by vigorously shaking the tube several times. Most of the reagent should dissolve, but some may remain undissolved. Dissolution will continue during incubation. When the reagent is dissolved, the

Figure B-1. Materials Required for *E. coli* Sampling and Testing



Figure B-2. Using the Pipette to Fill Colilert Tube



⁸ This protocol is based on a protocol developed by Dr. Robert H. Metcalf for use in low resource areas where a laboratory incubator is not available (Metcalf and Stordal 2010).

sample will be clear.

5. Incubate the tube at body temperature (35°C), to promote good bacterial growth. Tubes can be placed in a small sack or sock and held close to the body – and slept on at night (Figure B-3).
6. Examine the tubes after incubation for up to 24 hr (results are often evident in 10-18 hours [10 hours with heavy contamination and 18 hours with lesser contamination], but final examination should be done at 24 hours).

- a. First examine them in natural light (Figure B-4). If the water in the tube is clear, there is no *E. coli* or other coliform present. If the water in the tube is yellow, some coliforms (Total Coliforms) are present, but they may not be *E. coli*. You need to examine the sample with UV light to determine if *E. coli* is present, using the following procedure.
- b. If the water in the tube is yellow, examine the water in the tube under a long-wave length (365-nm) UV light in a dark environment (Figure B-4). Hold the light 5-inches away from the tube with the light shining away from your eyes and towards the sample. If the water in the tube fluoresces, then the sample contains *E. coli*.

Figure B-3. Incubating the Sample Using Body Heat

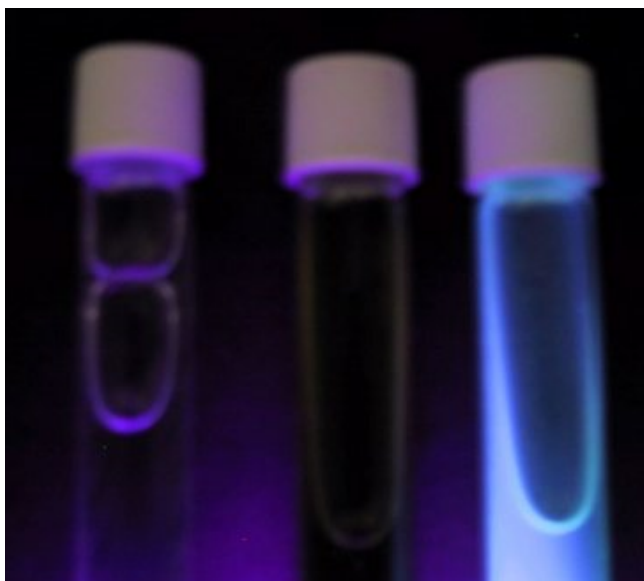


Figure B-4. Reading Results



Under Natural Light

Clear tube on left contains no coliform.
Yellow tubes contain Total Coliform.



Same Tubes Under Long-Wave UV Light

Tube in center contains Total Coliform, but no *E. coli*.
Fluorescent tube on right contains *E. coli*.

Reporting

1. Maintain a log of monitoring activities and record the following information in the log:

- Name of system owner;
 - Location of system;
 - Name of person who took and evaluated the sample;
 - Date and time of water sample collection;
 - Date and time of evaluation of the sample;
 - Results of evaluation (no coliform present; Total Coliform present but no *E. coli* present; or *E. coli* present); and
 - Date, time and nature of response with system owner.
2. Report information in the log to the CCAP Municipal Advisor and make the log available for his/her inspection.

ANNEX C

ROOF-HARVESTED RAINWATER SYSTEMS REQUIREMENTS IN EMMP

IEE Condition	Mitigation Measure	Monitoring	Timing	Responsible Party
The activity shall be designed and implemented using the principles and good construction practices provided in USAID's Sector Environmental Guidelines for Small-Scale Construction ⁹ and using best practices for roof-harvested rainwater, such as those of UNEP/OAS and IRD. ¹⁰	Same as for Small-Scale Construction for Activity 4, Climate Resilient House Construction	Same as for Small-Scale Construction for Activity 4	Same as for Small-Scale Construction for Activity 4	Same as for Small-Scale Construction for Activity 4
	Planning and Design <ul style="list-style-type: none"> Conveyance systems shall be appropriately sized for the area of the collection surface and rainfall patterns, and be constructed of an inert material. Tank designs shall be appropriately sized for the area of the collection surface, rainfall patterns and anticipated consumption needs, constructed of an inert material and include: <ul style="list-style-type: none"> A solid secure cover. A coarse inlet filter. An overflow pipe. A manhole, sump, and drain to facilitate cleaning. An extraction system that does not contaminate the water; e.g., a tap or pump. A soakaway to prevent spilled water from forming puddles near the tank. Catchment surfaces shall be made of nontoxic material. Painted surfaces should be avoided if possible, or, if the use of paint is unavoidable, only nontoxic paint should be used (e.g., no lead-, chromium-, or zinc-based paints). Overhanging vegetation should be avoided. 	Review and approval of proposed roof-harvested rainwater project	Receipt of proposal or contract/grant request	Deputy Chief of Party for Programs or designee
	Operation and Maintenance Develop and implement: <ul style="list-style-type: none"> A procedure for diverting from the storage tank the "foul flush" 	Review and approval of proposed roof-harvested rainwater project	Receipt of proposal or contract/grant request	Deputy Chief of Party for Programs or designee

⁹ USAID. 2014. Sector Environmental Guidelines: Small-Scale Construction. <http://www.usaidgems.org/Sectors/construction.htm>

¹⁰ UNEP/OAS. 1998. Rainwater harvesting from rooftop catchments. In: Sourcebook of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean. <http://www.oas.org/dsd/publications/unit/oea59e/ch10.htm> and International Relief and Development (IRD). 2013. Roof-Top Rainwater Harvesting Best Practices Guide. USAID-funded. http://www.ird.org/uploads/IRD_RWH_Guide_10June13.pdf

IEE Condition	Mitigation Measure	Monitoring	Timing	Responsible Party
	<p>(the water captured during the first 10 minutes of the first rainfall after a long dry spell).</p> <ul style="list-style-type: none"> • Periodic inspection and cleaning of the storage tank, including scrubbing of the inner walls and floors with a chlorine solution followed by thorough rinsing. • Periodic inspection and cleaning of gutters and downpipes • Maintenance of a secure cover on the storage tank. • Treatment of collected water before using it for drinking water. • Periodic maintenance on any pumps used to lift water out of the storage tank. 	Site inspection using the Monitoring Log for Roof-Harvested Rainwater Systems (Annex D of this EMMP)	Semi-Annually (at least once per year shortly after the first rainfall after a long dry spell)	Municipal Advisor initially and then transfer responsibility to Implementing Partner, including the responsibility to report to the Municipal Advisor on inspection results
	Each community system (those on schools, markets or other public structures) shall include establishment (or designation) and training of a community organization to maintain the system. If an existing community organization is designated, a written acceptance of the designation shall be secured.	<p>Review and approval of proposed roof-harvested rainwater project</p> <p>Written acceptance of maintenance responsibility from existing community organization (if so identified in proposal)</p>	Receipt of proposal or contract/grant request	Deputy Chief of Party for Programs or designee
The implementing partner shall develop and implement a training program for water recipients on the operation and maintenance of roof-harvested rainwater systems, the potential for microbiological contamination, and proper treatment for safe drinking water.	Develop and implement a training program for water recipients on the operation and maintenance of roof-harvested rainwater systems, the potential for microbiological contamination, and proper treatment for safe drinking water	Attendance at a sample of training events	During training campaign	Community Advisor
The implementing partner shall conduct follow-up inspections to ensure that proper operation and maintenance and treatment of drinking water are being practice	The implementing partner shall conduct follow-up inspections to ensure that proper operation and maintenance and treatment of drinking water are being practice	Site inspection using the Monitoring Log for Roof-Harvested Rainwater Systems (Annex D of this EMMP)	Semi-Annually	Implementing Partner
	The implementing partner shall report on its inspections	Report to CCAP on results of monitoring	Quarterly	Implementing Partner

IEE Condition	Mitigation Measure	Monitoring	Timing	Responsible Party
<p>Prior to drinking water provision, the project will prepare and receive approval for a Water Quality Assurance Plan (WQAP).</p> <p>The IEE had several specific conditions regarding the content of the WQAP, which are listed in the text below this table.</p>	<p>The WQAP will be developed as per the specific conditions listed below this table.</p> <p>The specific monitoring and mitigation measures will be determined in the WQAP.</p>	<p>To be determined in the WQAP.</p>	<p>To be determined in the WQAP.</p>	<p>To be determined in the WQAP.</p>

ANNEX D: MONITORING LOG FOR ROOF-HARVESTED RAINWATER SYSTEMS

Coastal City Adaptation Project Monitoring Log for Roof-Harvested Rainwater Systems

Site Name:	
Implementing Partner:	
Contract Number:	
Type of Activity:	

Date	Name of Inspector

Mitigation Measure	Date	Yes	No	If No, Action Taken
Can the owner of the system explain to you the procedure for diverting from the storage tank the "foul flush" (the water captured during the first 10 minutes of the first rainfall after a long dry spell)?				
If you are there shortly after the first rainfall after a long dry spell, does it appear from the condition of the water in the tank that they have used the procedure to divert "foul flush" from the tank?				
Can the owner of the system tell you the last time he/she inspected and/or cleaned the storage tank?				

Mitigation Measure	Date	Yes	No	If No, Action Taken
If the owner says the tank was cleaned within the last month, does the inside of the tank appear to be clean?				
Does the owner of the system have a schedule for inspecting or cleaning the tank?				
Have the owner describe to you how he/she cleans the tank. Does the description include: scrubbing of the inner walls and floors with a chlorine solution followed by thorough rinsing?				
Can the owner of the system tell you the last time he/she inspected and/or cleaned the gutters and downpipes?				
If the owner says the gutters and downpipes were cleaned within the last month, do they appear to be clean?				

Mitigation Measure	Date	Yes	No	If No, Action Taken
Does the owner of the system have a schedule for inspecting or cleaning the gutters and downpipes?				
Does the cover on the storage tank appear to be well-maintained and secure?				
Does the owner of the system treat the collected water before using it for drinking water?				
Can the owner of the system describe how he/she treats the water before using it as drinking water?				
If pumps used to lift water out of the storage tank, does the owner have a maintenance schedule for the pumps?				